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COMPUTER ANALYSIS OF THE
TEMPLIN-DARLEY TEST OF ARTICULATION

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled COMPUTER ANALYSIS OF THE TEMPLIN-DARLEY TEST OF ARTICULATION submitted by Mushtaq Ahmad Qureshi in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

This thesis presents a description of the Computer Analysis of The Templin-Darley Test of Articulation. The reason for developing this system was to provide the Speech Pathology - Audiology Department at the Glenrose Hospital with the ability to use a computer for the recording and analysis of the Templin-Darley Test of Articulation.

The time taken for the therapist to manually score this test is considerable; in a majority of the cases the therapist actually does not have enough time to do the complete analysis. With the implementation of such a system as that developed here, the therapist need only enter the patient's responses via terminal and the whole analysis is done by computer in on-line mode.

The main advantage of a system of this nature is to reduce the time in scoring these tests; however, it will also improve the quality of the analysis, because some items of the test do suffer in accuracy from a hasty scan in present manual procedures.

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CHAPTER I

ARTICULATION TESTING

1.1 Introduction

An articulation test, as the term is generally used, is a technique employed to measure the general speech production of an individual. Phonemes are the basic sounds that are used by all speakers of a given language. Phonemes represent the smallest differences in a language which serve to differentiate meanings within the language. The number of phonemes, or sound elements, in different languages varies. In English, 46 phonemes are usually recognized; the 'sh' sound in the English word 'shoe', represented by [ʃ], and [I], as in 'sit', are examples.

The purpose of an articulation test, then, is to compare the articulations that are actually used by an individual with the phonemic structure of his language. If he is unable to produce a reasonable approximation of each of the phonemes used in his language, he is said to have articulatory difficulties. On the other hand, if he can freely use all of the phonemes of his language, his speech difficulties, if any, are not articulatory. For example, an individual may pronounce 'wish' as [wuʃ]. If, however, [I] is among the phonemes he actually uses correctly in other words such as 'hit', 'sit' and 'fish', and if he can say

[wɪʃ] if he desires, then [wuʃ] would be an example of a pronunciation error rather than an articulatory error. Only if he has difficulty with [I] in some or all the combinations of words like 'sit', or 'wish' would his difficulty be seen as articulatory.

Articulation tests can be divided into three groups, according to the purpose for which they were designed - research, screening, or diagnostic. Relatively few have been designed for basic research purposes. The majority were designed with a clinical orientation, either as screening tests or as diagnostic tests.

Examples of research purposes would be:

(a) To isolate the phonemes actually used in a language. The goal in such testing is to determine whether a sound is meaningfully present or absent in a group rather than to determine the rightness or wrongness of the speech production of a particular individual.

(b) To compare the phonemic structure of different age groups within a language. Thus the phonemes used by two-year olds, five-year olds or any other age group can be isolated on a group basis. Such a research test implies that a standard or norm has already been set.

Some research groups have devised articulation tests for the purpose of investigating the speech of certain

handicapped groups, such as the hard-of-hearing or the blind.

Of the clinically oriented articulation tests, the screening test has the widest application. The purpose of the screening test is simply to decide whether the phonemic capacity or speech of the examinee is within the acceptable range for his particular age group, an adverse result indicating a need for more complete testing. The diagnostic test of articulation, on the other hand, is used to determine a need for therapy and to obtain an indication as to the specific nature of remediation. It provides detailed information about a child's ability to produce a wide range of speech sounds in a variety of positions in the word and in different phonetic contexts.

1.2 Techniques in Articulation Testing

Most commonly the articulation test is designed for use with children. The usual technique is to present specially selected pictures or objects to the child and ask him to name what he sees, and thereby, hopefully, obtain spontaneous utterences of certain pre-selected lexical items chosen for their phonetic contents. The quality of the information thus obtained from articulation testing is determined both by the precision of the instrument and the sophistication of the examiner in its administration and

interpretation, i.e. the method of eliciting the speech from the child and the linguistic sophistication of the investigator in its interpretation.

Many practising clinicians employ their own _ad hoc_ screening and diagnostic tests. However, commercially available tests like the Templin-Darley Test of Articulation [1], based on the results of Templin's lengthy research on the process of speech-sound acquisition in children [2], are major achievements in the field of articulation testing and have been widely recognized as such.

As the computer adaptation of the Templin-Darley Test of Articulation is the subject of this thesis, the test will be described in detail in the following sections.

1.3 The Templin-Darley Test of Articulation

The Templin-Darley Test of Articulation consists of two parts:

(a) Diagnostic Test

(b) Screening Test

The _diagnostic test_ consists of 141 test items. The various sound elements tested are:

11 vowels, e.g. [I] in 'sit'.

6 diphthongs, e.g. [ju] in 'music'.

55 consonants at initial, medial and final position, e.g. [θ] in 'thumb', 'bathtub', 'teeth'.

34 two-consonant blends, e.g. [pl-] in 'planting'.

19 combinations of consonant with syllabic or non-syllabic vowel [ɚ], e.g. [mɚ] in 'hammer' and [ɚm] in 'arm'

12 blends of syllabic or non-syllabic vowel [l], e.g. [-fl] in 'rifle' and as [-sl] in 'muscle'.

4 three-consonant blends, e.g. [str] in 'string'.

A four-page test form is available for use with these tests, a copy being given in Appendix A.

In order to evaluate a child's production of the speech sound elements selected for study, it is necessary that he produce each element. An appropriate word is selected for each element, one as familiar as possible to the young person and able to be represented pictorially with the minimum ambiguity for the child.

The examiner shows the child the picture for each element, and has the choice of:

> "(a) attempting to elicit the desired test word spontaneously by asking the child to name the object pictured or,
>
> (b) saying the test word and having the child repeat it after him." [1]

The former procedure is called a "spontaneous method" and the latter an "imitative method". For the diagnostic test, when assessment of a typical production of the test sound is

desired, the spontaneous method of testing is used. However, occasionally it is necessary for the examiner to say a word for the child if the child's production of all test sounds is to be obtained. Such imitative responses are more frequently necessary with testing younger children.

1.3.1 Recording of The Test Responses

On page 2 of the test form (see Appendix A) space is provided after each test sound to record the response of the child. For each single consonant, vowel, or diphthong an entry is made, in the appropriate space, using the following symbols:

> "(a) if the child produces the sound correctly, the fact is indicated by a check mark [✓].
>
> (b) If he substitutes another phoneme, the phonetic symbol representing that phoneme he uttered is entered.
>
> (c) If he omits a test sound in pronouncing the test word, the omission is indicated by a dash [-].
>
> (d) If he distorts a sound (that is, the sound is produced faultily although his production can be recognized as being an example of the desired sound) [x] is entered.
>
> (e) If the child does not attempt to produce the desired test word, [nr] is entered signifying 'no response'." [1]

In the case of consonant blends, the code given above is adapted so that the errors and correct articulations are readily identified for any given sound element. Thus if one phoneme of a two-consonant blend is produced correctly while the other is omitted, then the symbol for the correctly produced phoneme is entered and a dash written for the omission.

Following are some possible entries on the test form for the purpose of illustration, the numbers on the left indicating the item number on the form.

44 sw- xw
49 str xt-

60	t	✓	61	t	-
72	s	x	73	s	x

These entries indicate that single consonant [t] was correctly produced when presented in initial position at test item 60 but omitted in the final position at item 61, and [s] was distorted at both positions at items 72 and 73. For item 44 it indicates that [s] was distorted and [w] was produced correctly. For item 49 it indicates that [s] was distorted, [t] was produced correctly and consonant [r] was omitted.

1.3.2 Analysis

When the examiner has elicited all of the test articulations from the child, he is ready to analyse the results. Page 3 of the test form presents a series of analyses to be made.

A first step in the analysis of a child's test performance is to determine how his scores compare with those of his chronological peers. After counting the total number of test sounds correctly produced, for each sub-section 1-a to 1-j of the analysis sheet (see Appendix A) the examiner is referred to a table of norms for each to determine how the child's total score compares with those of his age group.

Further analysis to be done on the test results is as follows:

In sub-section 2-a of the test form entry is made of the errors recorded during the child's production of the vowels, diphthongs, and consonant singles under three categories of error: 'omissions', 'substitutions', and 'distortions'.

Sub-sections 2-b and 2-c of the analysis sheet are provided for the determination of whether the child was inconsistent in his errors. In sub-section 2-b the entry is

made of each consonant which the child incorrectly articulated in one position but which he correctly articulated as a single in at least one other position. For example, if consonant single [s] is correctly articulated in initial position, but incorrectly articulated in final position, [s] is entered in 2-b. In sub-section 2-c an entry is made of each consonant which was never articulated correctly as a single, but was correctly articulated in one or more blends or clusters. Since the diagnostic test provides for repeated testing of several consonant sounds in a variety of phonetic contexts, the information summarized can indicate to the therapist not only what needs to be corrected but also where to start in teaching a sound to the child.

After the appropriate information has been entered in sub-sections 2-b and 2-c on the analysis form, the sounds which the child has not correctly produced in any position or phonetic context remain in sub-section 2-a.

Where articulatory difficulties are indicated by the above, deeper appraisal of the child's articulation is made through further auditory stimuli given as below:

Each of these residual 2-a sounds is presented by the therapist in four ways as a pattern to be imitated: 1) as a single in isolation; 2) as a single in a syllable; 3) as a single in a word; 4) as a blend in a word, if the sound is a

consonant. The child is instructed to imitate the sound after the therapist articulates it. If the child correctly produces a sound following any of these auditory stimuli, the sound is entered in the appropriate column or columns of the analysis sheet. This is called the Stimulation Test.

In sub-section 2-e of the sheet the consistently misarticulated sounds are listed. These are all sounds which were never articulated correctly even after stimulation.

1.4 Screening Test

The screening test consists of 50 of the 141 items in the diagnostic test which have been found to discriminate best between good and poor articulation by pre-school and kindergarten children. These are the first 50 items on the test form (see Appendix A).

The same procedure of attempting to elicit spontaneous responses is followed as has been described for the diagnostic test. The child's performance on these items alone can be compared with that of his age group on these items. More importantly, they can serve to identify him as a child who does or does not need deeper study of his speech sound articulation. For this purpose, Templin [2] has prepared cut-off scores which separate adequate from inadequate performance at each age level.

CHAPTER II

THE COMPUTER AS A POSSIBLE TOOL

Recent years have seen a continual expansion of computer use and applications, including many aspects of health care. From business and medical records they have expanded in hospitals to cover a large range of patient management applications. Though the operational economies are sometimes an influence, most applications can only be justified by benefits in the form of improvement in the patient's care. The intent of this chapter is to see how the computer can be used as a possible tool in recording and analysis of the Templin-Darley Test of Articulation; and what advantages could thereby accrue.

Currently the state-of-the-art of direct analysis of human speech by computer cannot provide an adequate method for assessing a patient's responses, and these must be put into the system via an interpreter. A computer could display pictures to elicit speech from a child, or even generate stimulating sounds. However, appropriate facilities were not available to develop this aspect of the interface in the study reported here and presentation by computer of pictures is merely discussed in Chapter V as a future possibility. For this study, therefore, the examiner must act as an interpreter between the computer and the patient, both in

presenting the material and recording responses. The essence of the problem, then, is to achieve effective communication between two quite different sources, the speech therapist and the computer. One of these is capable of creative thinking but slow at calculating and prone to error. The other lacks significant intellectual powers but calculates at high speed and rarely makes mistakes.

It was thought if the response of the patient is stored in an array, then this will serve as a key to store the error sounds. Further, if a code is given for each type of error, i.e. for omission, distortion, or substitution, then this will help in determining the nature of the error.

With this information stored, plus prior storage of tables of norms for each age group, the analysis from subsections 1-a to 2-c of the test could be produced. Subsections 2-d and 2-e are the results of a subsequent test based on the results of the initial portion.

The time taken for the speech therapist to score this test manually is considerable; often not enough time is actually available to complete the test. But more importantly, some items can suffer in accuracy from a hasty scan, specially sections 2-b - "which of these phonemes, incorrectly articulated as singles in any position, were correctly articulated in at least one position?" and 2-c - "which of these phonemes, incorrectly articulated as

singles, were correctly produced in any of the clusters in which they were further tested?". For these sections the test sounds are randomly scattered throughout the 141 items of the test form. It is very easy for the therapist to miss these items, affecting adversely the quality of the analysis. But the computer can check these items consistently, once it is programmed to carry out these instructions.

CHAPTER III

DESIGN CONCEPTS

3.1 Introduction

In the medical environment full exploitation of the available computer resources depends on one very important factor - giving physicians or other health professionals direct control of these resources. From the viewpoint of these people, the paramount goal is to achieve direct communication between man and machine without sacrificing valuable time and effort to become experts in the art of computer programming and system operations.

This concept is the basis for the development of a system that will provide the Speech Pathology - Audiology Department at the Glenrose Hospital with a real-time scoring of the Templin-Darley Test of Articulation.

In designing such a system there are some basic points to take into consideration:

(a) The system must be flexible in its data handling, i.e. should not impose avoidable restrictions on the form of input data.

(b) The likelihood that incoming messages may contain errors must be realized, and provision made for correcting these errors so as to achieve accurate

results.

(c) To be of use, the system must give output which is readily understood by the user.

The intent of this chapter is to discuss these points in some detail.

3.2 Analysis of the Whole Problem

It is essential that, before such a system be implemented, current procedures and practice be understood. Such a systems analysis makes possible the definition of what could be done. The actual analysis involved talking with speech therapists at the Glenrose Hospital and observing the actual procedures.

In administering the Templin-Darley test the speech therapist works through 141 items of the test, asking the patient to pronounce each sound element and recording the responses on the test sheet. After completing all items, the therapist is ready to analyze the data thus obtained from a patient. Each of the correct or incorrect responses is initially recorded by an expression representing the sound produced. For analysis, each is classified as being the form of an omission, a distortion or a substitution, recorded by the therapist as indicated below. This is the key in the analysis of the results.

Patient Response	Therapist Recording
correctly produced	✓
omission	-
distortion	x
substitution	substituted sound

Meaningful communication between man and machine requires that each be able to present information to the other in a comprehensible way, and of course be able to sense the information provided by the other. Dialogue between computer and therapist allows for use of sequences of letters to represent the actual sound produced, with following interpretation by the computer.

Therapist Observation	System Interpretation
ok	correctly produced
om	omission
ds	distortion
any other	substitution

Clearly such a scheme is readily understood by the therapist.

3.2.1 Denoting Phonemes

Since all the sounds in this test are covered in the International Phonetic Alphabet (IPA), it would be desirable to use a special IPA type-ball which contains all those symbols, especially for the sub-sections 2-a to 2-e of the test sheet (see Appendix A).

Unfortunately there are two major problems with the only such type ball available (Camwil, Inc., Honolulu, USA; model 113M), namely:

-it does not have any digits,

-it is not compatible with a normal terminal keyboard.

The first of the two problems is more important because digits 0 through 9 are required to print out the patient's score and other quantitative results. This could be solved by interchanging type balls, using one for printing scores and norms, and then changing to an IPA type-ball to print sub-sections 2-a to 2-e. However, this would obviously interfere markedly with the administration of the test and was deemed unacceptable.

The second problem could be solved by putting special phonetic symbols on the terminal keyboard - merely at some expense. However, in view of the prior problem, it was not even tried.

Since all relevant sounds have an associated number on the test sheet, it would be possible to use this as a number-code for communication. Then, instead of entering the actual sound, its number is entered. For example, 'ð (i)' is item number 10 on the test sheet, so if a patient substitutes 'ð' for any sound, instead of entering 'ð' its corresponding number, that is 10, could be entered. This has the obvious disadvantage of requiring decoding of the sound into the sound-number and vice versa. Then, for example, for sub-section 2-b of the Analysis-Sheet (see Appendix A) the program has to print phonemes which were correctly articulated in at least one position. Using this scheme, if the program could output 12, 10, etc., the therapist is required to refer back to the test sheet for decoding into corresponding sounds, or to memorize scores of code values. This was seen as unsatisfactory from the speech therapist's point of view.

Since the majority of characters on the test sheet are in fact on the normal type ball, a less demanding substitution scheme would be possible by requiring only substituting the exceptions. Only 14 of the 141 items of the test are not available on the normal type ball, so this should present little difficulty for the speech therapist.

Even with these few substitutions it is imperative that the speech therapist comprehend and readily recognize the

substitute code. To ensure this aspect, the substitution scheme was established in consultation with a speech therapist at the Glenrose Hospital. So far as possible the substitution was done so as to represent the sound in question closely. For example, the phonetic alphabet 'θ' is 'th' sound, as produced in the English word 'thin'. If, then, 'θ' is substituted by 'th' for computer representation, it should not present any problem to the therapist to become familiar with such scheme. This last approach was the one adopted, the complete substitution scheme being given in Appendix B. Should it prove unsuitable over time, it may be possible to design a new type ball that contains several missing symbols but retains the digits and other necessary symbols.

3.3 Strategy And Algorithm

In designing any computer system for a user who is not familiar with computer programming, the system should be made flexible in its data handling and instructions for job operations should be kept simple.

For such a user it appears infeasible to ask a rigid set of questions or demand a rigid pattern of input. For instance, the system asks for a patient's 'AGE' and waits for the user's response. Because the age of the patient can exceed nine years two characters are allowed for in the response. But, if the system demands two characters always

then every time the age is less than 10 years, the user has to type a leading blank or zero. This would usually be more convenient for programming. However, it is distinctly inconvenient to the user and, since this test is designed basically to test quite young children who have speech problems, such a situation would be very common.

A better approach to this, then, will be to treat all responses as normal text and then convert the character string into a number after appropriate inspection. This method may cost some extra computing but will minimize the chances of making errors as well as facilitating the system's use and acceptance. The user merely enters '6' when that is the patient's age.

3.3.1 Step-1 Data-Input And Handling Of Errors

Processing of the patient-response findings requires knowledge of 50 responses if mere screening is being done, and of 141 responses when, as is usual at the Glenrose Hospital, the test is being used diagnostically. This suggests a procedure wherein the computer types out an item and then waits for the therapist's response. Since most of the test sounds are produced correctly by the patient, a choice should be given to avoid the typing of all 141 items. For this reason the input can be handled in either of two ways:

- full input
- abbreviated input

In full input the speech therapist has to type in all 141 responses; even if a sound is correctly articulated the therapist must enter 'ok' for it.

In abbreviated input, the therapist has to enter only the erroneous responses; other items are assumed to be correct. This approach is useful in reducing the amount of typing.

The therapist is given the option for the desired way of input in the beginning of the test and the system treats the input accordingly. For abbreviated input the entries can be either alphabetic, being a representation of a patient's response, or numeric, being a pointer to a different item. For such input the system treats all responses as alphabetic, detects the presence of a number by character-by-character analysis, and then, if the answer is numeric, converts the resulting string into a number. This scheme is also very useful in correcting errors. For example, when the user wants to go back to some item and give a different answer, he can do so by typing the item number that he wants to go to.

If, however, after completing the 141 items, the user realizes that some items should be changed, the system

should make such provision for change. This may be done by asking the user whether he wants to change data. If the user's reply is 'yes' then the system must make provision for recognizing a special end-cf-list response. For example 'END', which indicates that the user has finished making all corrections.

3.3.2 Step-2 Screening Test

The Screening Test consists of the first 50 items of the test sheet (see Appendix A). The patient's score on these 50 items is compared with those of patient's peers. Cut-off scores have been prepared which separate adequate from inadequate performance at each age level. The purpose of this test is to check whether the patient needs to be given the remaining test. Thus the first step in analysing the articulation test will be to compute the Screening Test score and compare it with the cut-off score of that age level. This will help the therapist to decide if the test should be continued. The computer may print a question ' DO YOU WANT TO CONTINUE THE TEST ?'- and wait for the user's response. It can then take the appropriate action depending on the response - yes or no, though it is the therapist's choice entirely - tc stcp cr continue the test.

3.3.3 Step-3 Fuller Comparison With Norms

If the therapist decides that the test should be continued, the next step is to acquire input for items 51 to 141 of the test sheet. Once the input is complete and correct the remaining analysis can be done. The first section of the analysis is the comparison of the patient's scores with his age group. These are sub-sections 1-a to 1-j of the test sheet, which are the following:

1-a Diagnostic Test (Table 1).

1-b Screening Test (Table 2).

Cut-off Score (Table 3).

1-c Initial and Final Consonant Singles (Table 4).

Initial Consonants (Table 5).

Final Consonants (Table 6).

How many of the 24 Consonants were defective in at least one position?

1-d Iowa Pressure Articulation Test (Table 8).

1-e /R/ and /R/ Clusters (Table 9).

1-f /L/ and /L/ Clusters (Table 10).

1-g /S/ Clusters (Table 11).

1-h Miscellaneous Clusters (Table 12).

1-i Vowels (Table 13).

1-j Diphthongs (Table 14).

The score of the patient for each of these sub-sections 1-a to 1-j must be computed and compared with that of his age

group. The tables of norms for different ages and sexes are stored in memory.

The problem with the items in these sub-sections is that they are scattered throughout the 141 items of the test sheet. For items 1-c to 1-j eight overlays have been prepared for manual use. They are given in Appendix C. For example, for 1-d - 'Iowa Pressure Articulation Test' - Overlay 8 was designed; as shown in Appendix C, this overlay consists of 43 test sounds which are spread all through the test sheet. The solution in the computer to this problem is to construct a table which has entries for all items which are in the overlay. For example, for 'Iowa Pressure Articulation Test', build up a table which will store all sound numbers in Overlay 8 (see Appendix C). Then the program can search through this table to pick up all those items which are correctly articulated, and thus calculate the score for the Iowa Pressure Articulation Test. All other overlays are treated like this.

3.3.4 <u>Step-4 Analysis Of Misarticulations</u>

Once the comparison with norms is finished, the next step is to do the analysis of misarticulations as set out on the analysis sheet (see Appendix A). These are sub-sections 2-a to 2-e on the sheet. This is the most important section of the articulation test, since it tells the therapist the

consistency of errors by the patient.

In sub-section 2-a, all error sounds, with an indication of the position of the error (I or F) - where I or F means Initial or Final position respectively - are given. This sub-section is served by Overlay 1, Overlay 2 and Overlay 3 (see Appendix C). Since the sheet calls for the list to discriminate between omissions, distortions and substitutions as well as between initial and final positions, six distinct tables must be assembled for this purpose. Figure 3.1 shows a part of Overlay 1 to illustrate this point more clearly.

Item#	Sound	Res.
5	l(i)	ok
6	v(i)	om
7	θ(i)	ok

Item#	I	Res.	Item#	F	Res.
			68	l	ds
69	f	ok	70	f	ok
			71	v	ok

Fig. 3.1: A part of Overlay 1

Suppose the sound '1(i)' - meaning '1' at initial position - is correctly articulated, when presented at item 5, but '1' at final position, as item 68, is distorted. This means '1' should be stored in a table which contains all distorted sounds at final position, for printing out in the appropriate part of 2-a.

Similarly for sub-section 2-b - "which of these phonemes, incorrectly articulated as singles in initial or final position as indicated above (i.e. in 2-a) were correctly articulated as singles in at least one position". Referring back to the illustration of Fig. 3.1, the sound '1' was produced correctly at initial position but distorted at final position. This means '1' should be stored separately indicating that it was correctly articulated at initial position.

3.3.4.1 Clusters Testing

The sounds which are incorrectly articulated as singles in any position are further tested in clusters involving those sounds. This requires several tables to be set up to take care of these clusters. There are 24 single consonants scattered throughout the test sheet for which further tests are made on clusters. The best solution is to store these clusters in different tables for each corresponding single

sound. Fig. 3.2 shows this point clearly. The column at the left shows the single sound, the middle column shows the item number on the test sheet for each pertinent cluster, and the right hand column gives composition of each of the clusters. Four of the 24 such sounds are given in Fig. 3.2, to show the approach taken.

Consonant	Item#	Clusters
m	38	sm-
	84	-mr
	94	-rm
	119	-mps
	121	-mp
n	39	sn-
	85	-nr
	95	-rn
	123	-nd
w	44	sw-
	45	tw-
	46	kw-

Consonant	Item#	Clusters
t	27	tr-
	41	st-
	49	str
	97	-rt
	101	rtsh
	106	-tl
	111	-lt
	116	-st
	122	-nt
	124	-kt
	125	-pt
	126	-ft

Fig. 3.2: Clusters Tables

Suppose, for example, the single consonant 'm' is incorrectly articulated. Then it becomes desirable to test 'm' in its clusters. The first step is to recognize the sound which is to be tested. Once the sound is recognized then control is transferred to a table which has all clusters involving 'm' as shown in Fig. 3.2. If the consonant 'm' is correctly produced in any of these clusters then 'm' should be printed for sub-section 2-c.

3.3.4.2 <u>Stimulation Test</u>

The sub-sections 2-d and 2-e of the test are based on results obtained in 2-a to 2-c. The sub-section 2-d deals with the Stimulation Test. Whether or not to give this test to a patient depends upon the speech therapist's judgement, so a choice must be offered the therapist. If the Stimulation Test is to be given, then the system should present those items for which stimulation is required. The Stimulation Test is given for those sounds which a patient incorrectly articulated in 2-a and subsequently in every position or cluster in which they further tested, i.e all sounds in 2-a but not in 2-b or 2-c. An appropriate table 'TABB' is constructed listing just those sounds; Fig. 3.3 is given to illustrate this.

The table 'TAB' of Fig. 3.3 contains all the sounds

which were incorrectly articulated as of sub-section 2-a, under the three headings: Omissions, Substitutions, and Distortions. The table 'TTAB' has two columns to show the sounds produced correctly in 2-b or 2-c. For example, sounds 'z' and 'ch' were incorrectly articulated in 2-a but were correctly articulated in 2-b in at least one position, and for column 2-c of 'TTAB' 'ng' and 's' were correctly articulated in any of the clusters in which they were further tested. This results in 'TABB' containing all error sounds of 'TAB' except for those which are encircled, because these sounds were produced correctly in 2-b and/or 2-c. It should be noted that the sound 'dz-' is entered twice in 'TAB', once for substitution and once for distortion, but entered only once in 'TABB'.

TAB

2-a		
Omissions	Substitutions	Distortions
none	r	sh
	th	dz-
	th-	s
	j	z
	ch	
	ng	
	z-	
	dz-	

TTAB

2-b	2-c
z	ng
ch	s

TABB

Stimulation Test	
1	r
2	th
3	th-
4	j
5	z-
6	dz-
7	sh

Fig. 3.3: Stimulation Test Table

Table 'TABB' thus becomes the list of phonemes to be displayed to the therapist for stimulated presentation to the patient. The results are provided to the computer and result in each phoneme being classed in sub-section 2-d as being correct in at least one occasion, though only after stimulation, or in 2-e as never articulated properly, even after stimulation.

If the Stimulation Test is not given then 2-d is necessarily void as 2-e will be:

$$2\text{-}e = 2\text{-}a - (2\text{-}b + 2\text{-}c),$$

that is, all the sounds in 'TABB'.

3.4 Summary

In this section the summary of the algorithm is given for a quick review.

STEP 1 Get input for first 50 items, check for errors.

STEP 2 Compute score for Screening Test. If further test required go to STEP 3, otherwise go to STEP 11.

STEP 3 Get remaining input, i.e. items 51 to 141, check for errors.

STEP 4 Construct tables for Overlay 1 to Overlay 8, compute patient's score for 1-a to 1-j to compare with those of his age group.

STEP 5 Do analysis for the sub-sections 2-a, 2-b, and 2-c.

STEP 6 Ascertain if the Stimulation Test is required, else go to STEP 9.

STEP 7 Construct table for Stimulation Test by,

TABB =2-a - (2-b + 2-c).

STEP 8 Construct table for 2-e by,

2-e = TABB - correct phonemes after stimulation

Go to STEP 10.

STEP 9 Get table for item 2-e by,

2-e = 2-a - (2-b + 2-c).

STEP 10 Print results.

STEP 11 STOP.

CHAPTER IV

PROGRAM DESCRIPTION

4.1 Introduction

The method of approach and the algorithm have been discussed in Chapter III. This chapter concentrates on a description of the program and instructions for its use.

The program is written entirely in FORTRAN, except for one subroutine (CHAR), which is written in Assembler language. It is written for execution on the University of Alberta IBM 360/67 computer, under the control of MTS (Michigan Terminal System) operating system. The object module, as compiled by the Fortran G compiler, resides on permanent disk file TEMPLIN. The program is composed of three routines: MAIN program, subroutine ALTER and subroutine CHAR; these are dicussed in separate sections of this chapter. The tables of norms for ages 3 to 8 years and the 141 items of the test form are also stored on MTS line file TEMPLIN. They are read in by MAIN in the beginning of the test.

The program is written for use in terminal-mode, i.e. with the user typing in input via a terminal and getting the output on the terminal.

4.2 MAIN Program

The MAIN program is responsible for getting the input from the user and doing the entire analysis of the test. MAIN can be divided into three sections:

-Input Section.

-Calculation of scores section.

-Analysis of misarticulations section.

4.2.1 Input Section

The Input Section is strictly in conversational mode, i.e. the program displays requests and awaits the user's responses. First the program collects the patient's personal data: name, age, etc. Then it asks for the patient's responses for 50 items for the screening test and then, if the test is continued, for items 51 to 141, building up an array that stores the responses for comparison with an ideal array. This array of the patient's responses is called 'CHECK'. Input is collected in either of two ways:

- abbreviated input
- full input

In the case of the abbreviated input option, the response array 'CHECK' is filled initially with 'ok' answers, which means that all the test sounds are assumed to

be correct. Then any item of the test that is not produced correctly is replaced by a contrary indication.

In full input no such assumptions are made; the user has to type in all the 141 responses, even if the test sound is produced correctly, and 'CHECK' is filled with actual responses.

Whichever way is used, once the input is complete MAIN asks if there are any changes to be made in the input data. If the user's reply is 'yes' then the subroutine ALTER is called at this point by MAIN. This routine asks for a new response to replace the old response. The description of ALTER is given in 4.3 below. After the user has finished with all the corrections, the program passes out of conversational mode and starts analysing the test responses.

4.2.2 Calculation of Scores

Calculation of scores is the first step in this analysis based on different overlays (see Appendix C). These scores are for sections 1-a to 1-j, as described in Chapter III, of the analysis sheet. MAIN internally constructs tables which take care of these overlays. Each table has entries for item numbers of that overlay. A part of Overlay 8 and corresponding responses in 'CHECK' are shown in Fig. 4.1.

Table
corresponding
Overlay 8

79	k(m)
80	g(m)
81	f(m)
82	s(m)
83	z(m)
86	-pr
90	-kr

CHECK

Index	Res
79	ok
80	om
81	ds
82	ok
83	ok
84	ok
85	ok
86	ok
87	om
88	ok
89	ok
90	ok

Fig: 4.1 Part of Overlay 8, with Associated Part of CHECK

The items in the overlay are compared against corresponding responses in 'CHECK'. If the response is 'ok' 1 is added to the score of Overlay 8 which calculates the score for the Iowa Pressure Test of Articulation. For Fig. 4.1 there are 5 'ok' answers, indicated by arrows, so the

total of 5 is contributed towards the score of Overlay 8. All other overlays are treated in the same way, with the exception of those relating to sub-section 1-c which has to have four scores calculated viz:

(i) Initial and Final Consonant Singles.

(ii) Initial Consonants.

(iii) Final Consonants.

(iv) How many of the 24 consonants were defective in at least one position?

For these items MAIN arranges the 24 consonants in initial and final positions respectively. These consonants are given by Overlay 1 (see Appendix C). The array 'CHECK' is checked against these consonants at their initial and final positions and separate scores calculated as follows:

If the response in 'CHECK' is 'ok' for both positions, then (i) is increased by 2, while (ii) and (iii) are each increased by 1.

If the consonant is correct at initial position, each of (i), (ii) and (iv) is increased by 1.

If the consonant is correctly produced in the final position, then (i), (iii) and (iv) are each increased by 1.

If the consonant is incorrect at both positions, then 1 is added to (iv), because that consonant was defective in at least one position.

Once the scores are calculated for sub-sections 1-a to 1-j of the analysis sheet, these are printed along with the norms and standard deviations of the patient's age group.

4.2.3 Analysis of Misarticulations

Analysis of misarticulations follows the calculation of scores, i.e. the analysis relating to section 2 of the analysis sheet. The sub-section 2-a of the analysis is to - "list all the error sounds, indicating the position of error". The indices of the 24 consonant singles are stored in two arrays, for their initial and final position. These indices are compared with those of 'CHECK'. For each position the nature of the error is noted from the response array. The program makes six tables to store these errors according to their positions. Each time an entry is made in these tables, a count is kept for each table to keep track of number of defective sounds, for later printout.

The next step is to check the above error sounds and find whether the sounds are produced correctly in at least one position. That is, the erroneous sounds are checked with the same sounds at other positions in 'CHECK' , and if a sound is correct in at least one position in array 'CHECK' , it is stored for sub-section 2-b.

The third step for analysis of the misarticulations is to check these single error sounds in their clusters. The

clusters-search procedure can be understood from Fig. 4.2.

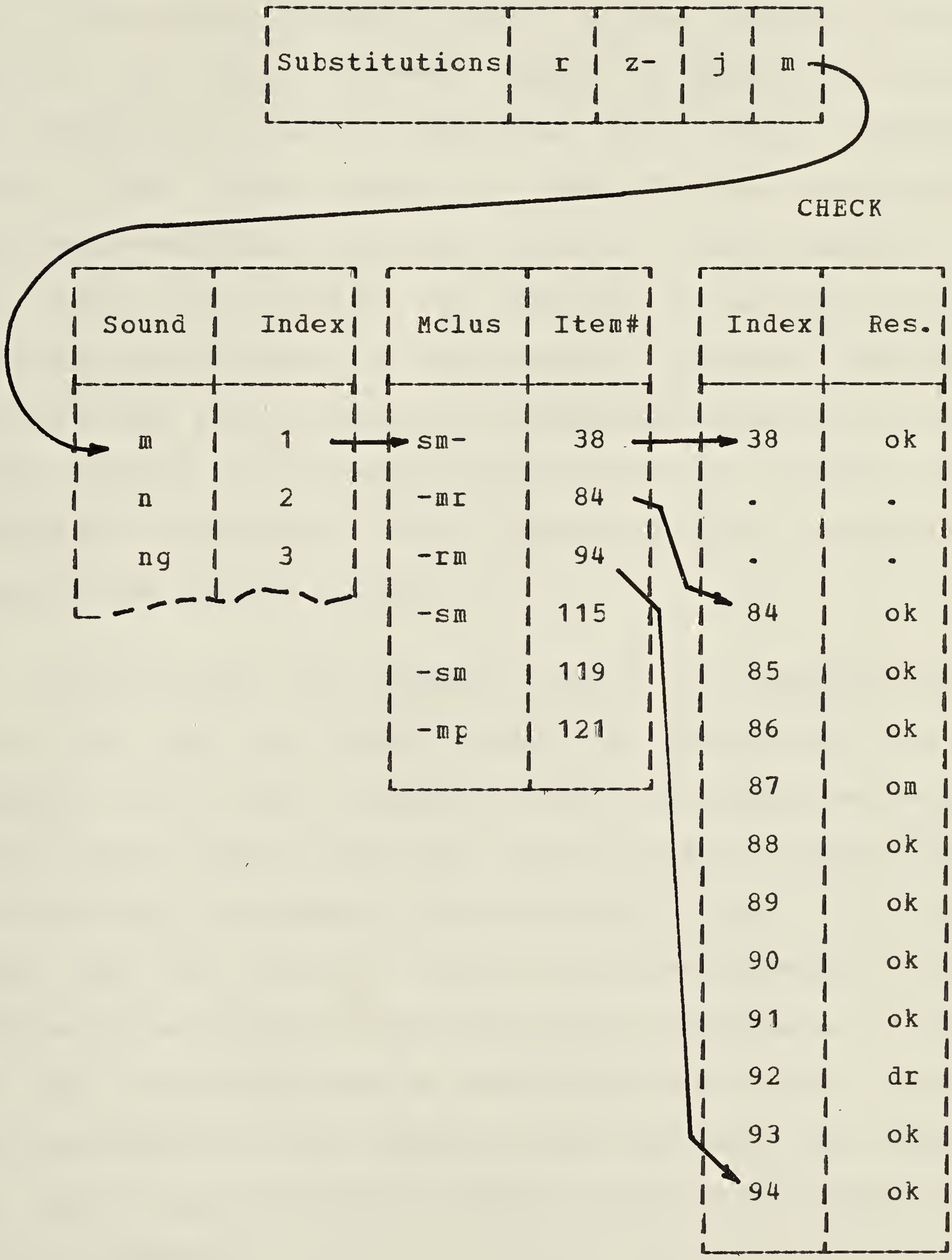

Fig 4.2: Clusters-Checking Procedure

Suppose that consonant single 'm' was substituted by some other sound, necessitating a check of all clusters which involve 'm'. This erroneous sound is matched in another table which has an index associated with every consonant single. This index points to a table that has entries for all the clusters for that sound. Then all the clusters in that table are checked by reference to the items in the response array 'CHECK'. If the sound is produced correctly anywhere in these clusters, the program indicates that the sound, though incorrectly articulated as single, is articulated correctly in at least one of the clusters in which it was further tested.

At this point the program reverts to conversational mode. The user is asked whether the Stimulation Test is required. If the user's reply is 'yes' the program makes the table called 'TABB', which has all the sounds of sub-section 2-a excluding the sounds of sub-sections 2-b and 2-c. This means that the program picks up all the erroneous sounds which were not produced correctly in any position of a test word or in the clusters in which they were further tested. The preparation of this table has been described in Chapter III. The user is asked to enter a response for each sound after stimulation.

Finally the sounds which were not correctly articulated even after stimulation testing, i.e. the sounds never

correctly articulated in 'TABB', are extracted from 'TABB' to indicate that these sounds were never produced correctly anywhere in the test. If, however, the Stimulation Test is not given to the patient, then 'TABB' is printed as a whole for sub-section 2-e.

4.3 Subroutine ALTER

This subroutine is called at two points by the MAIN program, after taking first the 50 responses from the user, and, when the test is continued, after the user has given answers for 141 items. In each case MAIN asks whether any changes are required. If the user's reply is 'yes', the routine ALTER is invoked, to get new input from the user to replace the old. The user is asked to give each revised response preceded by its item number. As many changes as required can be made. As soon as the user is finished making all the necessary corrections, 'end' is entered by the user. At this point the subroutine sets signals and control reverts to MAIN.

4.4 Subroutine CHAR

The purpose of this subroutine is to convert a character string into a different format. The reason for this conversion is that the input is treated as a string of characters rather than a number of fixed size. The analysis

is done character-by-character. If the first character of the input string is found to be numeric, the resulting input string is converted into a numeric field. If, however, the first character is not numeric, the string is converted into a character field of fixed length, allowing further checking for 'ok', 'om', or 'ds' in one comparison, instead of checking one character at a time. This subroutine is written in IBM 360 Assembler language and also resides on disk file TEMPLIN.

4.5 <u>User's Instructions</u>

This section provides instructions for the user in the operation of this program.

As the program is written for terminal-mode the first step is to initiate a terminal session. Access to the IBM 360/67 computer at the University of Alberta Computing Centre can be achieved via IBM 2741 hard-wired or dial-up terminals. Immediately the connection to the computer is made, a '#' is typed automatically on the left margin of the terminal paper, indicating that MTS is waiting for an input from the user. The first user entry must be a SIGNON command which takes the form:

    SIG CSID

where CSID is the user's Computing Services identification number.

The computer should then type:

    #PASSWORD ?
    ?WWWWWW

And leave the type ball positioned at the first character of the mask, i.e. the string of overprinted symbols, making it illegible to any observer. After the user has typed in his password, MTS again types '#' and awaits the next user entry. At this point the user can access the program by making the following entry:

    sou templin

After this line is entered the user has finished entering all the necessary requests and the program starts conversation with the user. The following requests are then made by the program:

PATIENT ID

NAME

AGE

SEX

EXAMINER

DATE

After printing each such line on the terminal, the program waits for the user's response; after each entry the user must depress the carriage return key on the terminal.

The specifications for this information are as follows.

'PATIENT ID' is the Speech Pathology - Audiology Department's patient identification number, up to maximum of 6 digits.

'NAME' is patient's name with maximum length of 20 characters.

'AGE' is the patient's age. If the age is less than 3 years or over 8 years it may be entered as such, but the program internally converts any age less than 3 or over 8 to 3 years and 8 years respectively, because the table of norms covers only from 3 years to 8 years of age.

'SEX' is patient's sex, '1' must be entered for male and '2' must be entered for female.

The 'EXAMINER' field is for the speech therapist's name with maximum length of 20 characters.

'DATE' is the date on which the test was administered. Any appropriate style may be used, the computer paying no attention to the contents i. e. ignoring them completely. Possible entries for the date include 1972/10/10, 10/10/1972, 10 Oct. 1972.

4.5.1 Input Division

After the user has typed in all the above information, the program is ready to accept the patient's response. The first thing the user is asked is:

DO YOU WANT ABBREVIATED INPUT? (YES OR NO)

The user must reply 'yes' or 'no'. Whichever input option is chosen, any imperfect patient response must be entered in one of following ways:

for omission	om
for distortion	ds
for substitution	symbols for the substituted sound.

For unavailable IPA symbols on the normal type ball, the substitution scheme in Appendix B must be used. The user must become familiar with this substitution scheme.

For full input, each correct response must be entered as 'ck'. For abbreviated input , only the defective sounds need be entered. For example, if item number 1 to item number 5 of the test are articulated correctly and 6 is articulated incorrectly, then, following the computer's presentation of the first item '1 er' on the terminal, the user should type in '6' to go to item number 6, as shown in the following example.

1 er 6

The program then prints the number and specification of the nominated item i.e. '6 v(i)' in this case, and again

awaits user's response. After the user has typed in a response for this item the program will automatically type the next item of the test, i.e. item number 7 in this example. The above mentioned procedure can be repeated each time the user wants to skip some items. The user can type 'ok' as a response if desired, and then the computer will automatically step on to the next item; this may be the prefered practice where an odd correct pronunciation intrudes between incorrect ones.

Another point should be noted here, that the user can also go back to correct some items. Again considering the above example, if the user wants to go back to item number 2 from item 7 and give a different answer, he should type in '2', the program types out:

2 ju

and awaits the user's entry. After the new entry has been made, the next line printed will be:

3 r(i)

It should be noted that the program clears all subsequent items back to 'ok' condition, so it will not be wise to use this procedure merely to correct one far distant error; for such a situation the procedure given in 4.5.2 below should be followed.

In _full input_ option, responses for all the 141 items

are required; that is all the items must be entered even if they are produced correctly.

4.5.2 Corrections of Errors

After acqiuring the first 50 items for input - for the Screening Test - the program types in the following message:

DO YOU WANT ANY CHANGES IN DATA?

If some corrections are desired, the user must respond with 'yes'. The following requests are then made by the program:

ENTER REPLACEMENT ("END" WHEN DONE)

ENTER DEFECTIVE ITEM NO.

For example, if item number 6 is to be corrected from 'ok' to 'om', this can be achieved by:

ENTER REPLACEMENT ("END" WHEN DONE) om

ENTER DEFECTIVE ITEM NO. 6

After the user has made all the necessary changes, he must enter 'end' to tell the program that he has finished all the corrections.

Example

ENTER REPLACEMENT end

4.5.3 Screening Test

After the first 50 items are typed in by the user and they are ascertained to be correctly entered, the program calculates the Screening Test score and prints it along with the cut-off score of the patient's age group. Supposing that score for the Screening Test of a 6 year old patient is 26, then the program types in :

```
SCREENING TEST      26
CUT-OFF SCORE       34
```

These two lines are followed immediately by the computer request:

```
DO YOU WANT TO CONTINUE THE TEST?
```

4.5.4 Core Diagnostic Test

If the remainder of the test is required, 'yes' must be typed in, 'no' otherwise. If the test is to be continued the program will ask for input for the remaining items, i.e. from 51 to 141. Should the user want to make any corrections on these items, the procedure given in 4.5.2 above should be followed.

4.5.5 Stimulation Test

After the input for all the 141 items is complete, the

analysis up to sub-section 2-c is done without any interruption. At this point it is up to the user to decide whether the Stimulation Test is to be given to the patient. The program displays the following message.

DO YOU WANT STIMULATION TEST?

And awaits the user's response; again the choice must be made between 'yes' and 'no'.

If the Stimulation Test is required, the program picks up all the erroneous sounds which require stimulation and types them on the terminal. For every sound correctly produced after stimulation 'ok' should be entered. If the sound is incorrectly produced 'no' should be entered. The program presents the sounds repeatedly under three headings:

- in isolation
- in a syllable
- in a word

A choice is given after each to continue or stop the test, because sometimes it is very hard to get responses from a child for all the stimuli tested. Thus after each set the program asks:

DO YOU WANT TO CONTINUE?

The choice should be made between 'yes' and 'no'.

After the Stimulation Test is completed, the program prints all the sounds which were never articulated correctly anywhere in the test for sub-section 2-e, and stops.

If another patient's test is required (or to repeat the previous one), the user has to type in 'sou templin' and then the program will automatically resume the test.

To close the dialogue with the computer, the user has to type the MTS SIGNOFF command, which takes the form:

$SIG

It should be noted that computer charges include a fee for 'connect time', so that this SIGNOFF procedure should be used whenever the terminal is to be left unused for fifteen minutes or longer. Resumption requires restarting at the beginning of the user's instructions.

The output of the program is given in Appendix D.

CHAPTER V

DISCUSSION

The objective of the research presented in this thesis was to provide the Speech Pathology - Audiology Department at the Glenrose Hospital with the ability to use a computer for the recording and analysis of the Templin-Darley Test of Articulation. The main advantage of a system of this nature is to facilitate the work of the speech therapist in analysing the test. Currently such a test is scored manually. This takes considerable time; in a majority of the cases the therapist actually does not have enough time to complete the scoring and analysis of the test, but merely extracts the more significant findings. With the implementation of such a system as that developed here, the therapist need only enter the patient's response via terminal and the whole analysis is done by computer in on-line mode.

The benefit of such a system is not only to save the time in scoring these tests but also to improve the quality of the analysis. The program was appraised on a number of cases already scored manually; in a majority of cases the manual analyses were found to be incorrect, many by a considerable margin. Although discrepancies did not vary the salient conclusions but only the degree of impairment, this

[illegible]

[illegible]

[illegible]

[illegible]

fact alone may well justify the use cf computer to achieve accuracy as well as speed over the manual procedures.

Since this system will act as an experimental model, it can be carried on to some useful extensions provided the response is encouraging. Some possible areas of extensions are discussed in this chapter.

5.1 Display Terminal

As mentioned in Chapter III, the analysis of the test cannot be started until all the test responses are entered. This fact presents the problem of entering data to the computer. The abbreviated input, allowing only the the defective sounds, reduces this problem. But the terminal input may be distracting for the patient, even with the use of silent terminals.

An alternative approach, that has the computer presenting the pictures, would use the IBM 2760 Optical Image Unit. This unit, which operates in conjuction with a typewriter terminal, allows for images to be rear-projected onto a viewing screen from 16 mm film and for selected data to be transmitted tc the computer by touching a sense probe on the segment of the screen where the required information appears. Fig. 5.1 illustrates the '2760' unit.

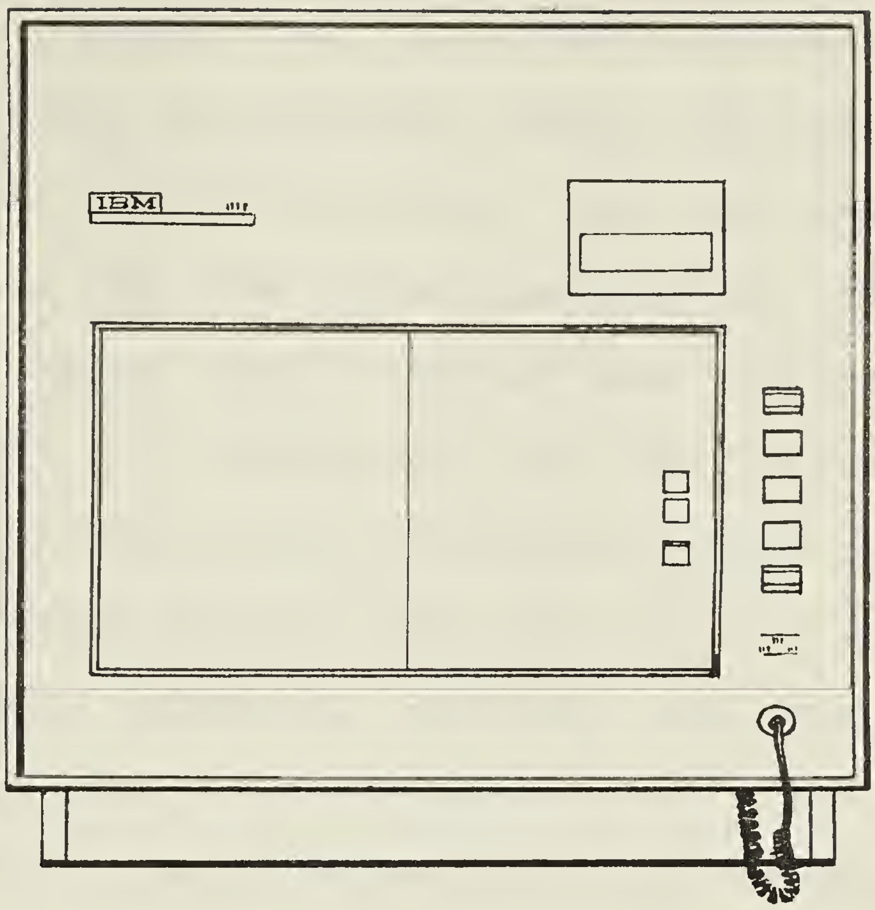

Fig. 5.1: IBM 2760 Optical Image Unit

The right side of the screen accommodates variable data through the use of a cassette, up to maximum of 128 images, the left side identifies relatively permanent information by use of a slide. The 9ins. x 14ins. viewing screen provides 240 response points for the selection of the displayed data using the probe.

The test pictures prepared to elicit the speech from a child could be displayed on the right side of the screen and the left side of the screen used to transmit the patient's response for that particular test item. This would save the therapist's showing the test pictures to the child and could

also act as a stimulant in capturing the child's interest. Since the cassette has only 128 frames and there are 141 test items, some frames would contain more than one picture. One could put consonant singles, for their initial and final positions, on the same frame. The computer would recognize situations where more than one item appears on the frame, and go to the next frame only after the responses for all the items on that frame had been recorded. The left side of the screen could display words like 'ok', 'om', and 'ds', for correctly produced, omitted, and distorted phonemes respectively. For substitutions, one could also display symbols for all the phonemes so that by touching the desired phonemes the substitutions could be transmitted. In case of clusters it would be necessary to transmit more than one phoneme at a time, so a symbol, indicating the end-of-entry, should be displayed. By touching this symbol the computer would know that response had been entered for the previous item and would go to the next frame, after interpretation of each probe entry.

A record of responses and the results of analyses would be printed on the typewriter component as usual.

5.2 History Files

Another useful extension would be to create the patient history files on the computer. This would allow the

therapist to retrieve any previous test performance by the patient, and compare it with the present performance. Since each patient has a unique identification number, the search could be performed on this key.

As the data base on a significant number of patients accumulates an interesting study would be to find out the general tendency of errors made by a particular age group. For example, if the patients are isolated on age group basis, then it could be found out which phonemes are generally distorted or omitted by a particular age group. For substitutions, the frequency of specific substitutions could be identified for each particular phoneme. From the linguistic point of view it may also suggest the developmental pattern of articulation in young children.

5.3 Special Character Set

The substitution scheme for the missing IPA symbols on the normal type ball has been prepared very carefully. However, in order to get optimal output from the therapist's point of view a special type set which has all the IPA symbols and the digits 0 to 9 should be provided. This could be achieved for the common terminal character set by substituting the 14 special symbols for the characters, '<', '>', '*', '¢', '¬', '-', '+', '&', '#', '!', '|', ':', '"', and '@'.

For the familiar terminals based on the IBM selectric typewriter this would require manufacture of a special type ball; for such other terminals as the 'Silent 700' that use a dot technique a special circuit board would be required. In either case a basic outlay of $1,000 would probably suffice.

Should the system developed already prove of real and continuing value, it is suggested that this modest outlay be made. The program would need minor adjustment to accommodate the changes, but the overall result would surely enhance the system and bring it to the point that was orignally intended - a system that is fully compatible with the normal functioning of the speech therapists.

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APPENDIX A

The following pages contain a copy of the Templin-Darley test-sheet.

IOWA

TEMPLIN–DARLEY TESTS OF ARTICULATION

Articulation Test Form

Published by the Bureau of Educational Research and Service,
Division of Extension and University Services
The University of Iowa, Iowa City, Iowa 52240

Name ______________________________

Date ______________ Age ________ Sex __________

Examiner ___________________________

Screening Test

1. ɝ ___	26. br- ___
2. ju ___	27. tr- ___
3. r(i) ___	28. dr- ___
4. r(m) ___	29. kr- ___
5. l(i) ___	30. gr- ___
6. v(i) ___	31. fr- ___
7. θ(i) ___	32. θr- ___
8. θ(m) ___	33. ʃr- ___
9. θ(f) ___	34. pl- ___
10. ð(i) ___	35. kl- ___
11. ð(m) ___	36. gl- ___
12. ð(f) ___	37. fl- ___
13. z(i) ___	38. sm- ___
14. ʃ(i) ___	39. sn- ___
15. ʃ(m) ___	40. sp- ___
16. ʃ(f) ___	41. st- ___
17. ʒ(m) ___	42. sk- ___
18. j(i) ___	43. sl- ___
19. j(m) ___	44. sw- ___
20. tʃ(i) ___	45. tw- ___
21. tʃ(m) ___	46. kw- ___
22. tʃ(f) ___	47. spl- ___
23. dʒ(i) ___	48. spr- ___
24. dʒ(m) ___	49. str- ___
25. pr- ___	50. skr- ___

Consonant Singles

Initial	Final
51. m ___	52. m ___
53. n ___	54. n ___
	55. ŋ ___
56. p ___	57. p ___
58. b ___	59. b ___
60. t ___	61. t ___
62. d ___	63. d ___
64. k ___	65. k ___
66. g ___	67. g ___
	68. l ___
69. f ___	70. f ___
	71. v ___
72. s ___	73. s ___
	74. z ___
	75. ʒ ___
76. h ___	
77. w ___	
	78. dʒ ___

Other Pressure Consonants

79. k(m) ___
80. g(m) ___
81. f(m) ___
82. s(m) ___
83. z(m) ___

ɚ

Syllabic	Non-Syllabic
84. -mɚ ___	94. -ɚm ___
85. -nɚ ___	95. -ɚn ___
86. -pɚ ___	96. -ɚp ___
87. -bɚ ___	97. -ɚt ___
88. -tɚ ___	98. -ɚd ___
89. -dɚ ___	99. -ɚk ___
90. -kɚ ___	100. -ɚf ___
91. -gɚ ___	101. -ɚtʃ ___
92. -ðɚ ___	102. -ɚdʒ ___
93. -ʃɚ ___	

Additional l clusters

103. bl- ___	110. -lp ___
104. -pl̩ ___	111. -lt ___
105. -bl̩ ___	112. -lk ___
106. -tl̩ ___	113. -lf ___
107. -kl̩ ___	114. -lz ___
108. -gl̩ ___	
109. -sl̩ ___	

Additional s clusters

115. -sm ___
116. -st ___
117. -sk ___
118. -ks ___
119. -mps ___

Other Clusters

120. -ŋk ___
121. -mp ___
122. -nt ___
123. -nd ___
124. -kt ___
125. -pt ___
126. -ft ___

Additional Vowels

127. i ___
128. ɪ ___
129. ɛ ___
130. æ ___
131. ʌ ___
132. ɚ ___
133. ɑ ___
134. ɔ ___
135. ʊ ___
136. u ___

Diphthongs

137. oʊ ___
138. aʊ ___
139. eɪ ___
140. aɪ ___
141. ɔɪ ___

ANALYSIS SHEET

1. Comparison with Norms

		Score	Norm
1-a.	Diagnostic Test (Table 1):	____	____
1-b.	Screening Test (Table 2):	____	____
	Cut-off Score (Table 3):	____	____
1-c.	Initial and Final Consonant Singles (Table 4):	____	____
	Initial Consonants (Table 5):	____	____
	Final Consonants (Table 6):	____	____
	How many of the 24 consonants were defective in at least one position?	____	
1-d.	Iowa Pressure Articulation Test (Table 8):	____	____
1-e.	/r/ and /ɚ/ Clusters (Table 9):	____	____
1-f.	/l/ and /l̩/ Clusters (Table 10):	____	____
1-g.	/s/ Clusters (Table 11):	____	____
1-h.	Miscellaneous Clusters (Table 12):	____	____
1-i.	Vowels (Table 13):	____	____
1-j.	Diphthongs (Table 14):	____	____

2. Analysis of Misarticulations

Analyze the subject's production of the phonemes listed as singles (Overlay A, Initial and Final Consonant Singles; Overlay G, Vowels; Overlay H, Diphthongs).

2-a. List all error sounds, indicating position of error (I or F)

Omissions	Substitutions	Distortions

2-b. Which of these phonemes, incorrectly articulated as singles in the initial or final positions as indicated above, were correctly articulated as singles in at least one position?

____

2-c. Which of these phonemes, incorrectly articulated as singles in any position, were correctly produced in any of the clusters in which they were further tested?

____

2-d. Which phonemes, not correctly produced as singles in any position or subsequently in clusters, were correctly produced following stimulation as described below?

As a Single			In a Cluster
In isolation	In a syllable	In a word	In a word
________	________	________	________
________	________	________	________
________	________	________	________

2-e. The following phonemes were never articulated correctly anywhere in the test or following any type of stimulation:

____

3. Factors Possibly Related to Patterns of Misarticulation

____

____

____

ADDITIONAL OBSERVATIONS

Description of distortion errors noted on record sheet:

____

____

____

____

Rating of intelligibility of contextual speech:

________ Readily intelligible

________ Intelligible if listener knows topic

________ Words intelligible now and then

________ Completely unintelligible

Errors noted in contextual speech not noted on articulation test:

____

____

____

____

____

Description of testing situation:

____

____

____

____

APPENDIX B

Substitution-scheme for the IPA symbols unavailable on the normal type ball.

IPA Symbol	Substituted Symbol
ɝ	er
θ	th
ð	th-
ʃ	sh
ʒ	z-
tʃ	ch
ɲ	ng
ɚ	r
ɛ	E
æ	ae
ʌ	A
ɔ	O
u	U
dʒ	dz
ɭ	l

APPENDIX C

Overlays

The following pages give the eight existing overlays used for calculating the scores and doing the analysis of misarticulations.

3. r(i)

5. l(i)
6. v(i)
7. θ(i)

9. θ(f)
10. ð(i)

12. ð(f)
13. z(i)
14. ʃ(i)

16. ʃ(f)

18. j(i)

20. tʃ(i)

22. tʃ(f)
23. dʒ(i)

Overlay 1 - - Consonant Singles, Initial and Final

Consonant Singles

Initial	Final
51. m	52. m
53. n	54. n
	55. ŋ
56. p	57. p
58. b	59. b
60. t	61. t
62. d	63. d
64. k	65. k
66. g	67. g
	68. l
69. f	70. f
	71. v
72. s	73. s
	74. z
	75. ʒ
76. h	
77. w	
	78. dʒ

Overlay 2 - - Vowels

1. ɝ

Additional Vowels

127. i

128. ɪ

129. ɛ

130. æ

131. ʌ

132. ɚ

133. ɑ

134. ɔ

135. ʊ

136. u

Overlay 3 - - Diphthongs and Combination

2. ju

Diphthongs

137. oʊ

138. aʊ

139. eɪ

140. aɪ

141. ɔɪ

Overlay 4 - - Clusters involving /r/ and /ɚ/

26. br-
27. tr-
28. dr-
29. kr-
30. gr-
31. fr-
32. θr-
33. ʃr-

ɚ

Syllabic	Non-Syllabic
84. -mɚ	94. -ɚm
85. -nɚ	95. -ɚn
86. -pɚ	96. -ɚp
87. -bɚ	97. -ɚt
88. -tɚ	98. -ɚd
89. -dɚ	99. -ɚk
90. -kɚ	100. -ɚf
91. -gɚ	101. -ɚtʃ
92. -ðɚ	102. -ɚdʒ
93. -ʃɚ	

48. spr-
49. str-
50. skr-

25. pr-

Overlay 5 - - Clusters involving /l/ and /l̩/

34. pl-
35. kl-
36. gl-
37. fl-

43. sl-

47. spl-

Additional
l clusters

103. bl-
104. -pl̩
105. -bl̩
106. -tl̩
107. -kl̩
108. -gl̩
109. -sl̩

110. -lp
111. -lt
112. -lk
113. -lf
114. -lz

Overlay 6 - - Clusters involving /s/

38. sm-
39. sn-
40. sp-
41. st-
42. sk-
43. sl-
44. sw-

47. spl-
48. spr-
49. str-
50. skr-

109. -sl

Additional s clusters

115. -sm
116. -st
117. -sk
118. -ks
119. -mps

Overlay 7 - - Miscellaneous Clusters

Other Clusters

120. -ŋk
121. -mp
122. -nt
123. -nd
124. -kt
125. -pt
126. -ft

45. tw-
46. kw-

Overlay 8 - - Iowa Pressure Articulation Test

26. br-
27. tr-
28. dr-
29. kr-
30. gr-

34. pl-
35. kl-
36. gl-

14. ʃ(i)
15. ʃ(m)
16. ʃ(f)

38. sm-
39. sn-
40. sp-
41. st-
42. sk-

45. tw-

23. dʒ(i)

49. str-

60. t

64. k
66. g

72. s

65. k
67. g

70. f

73. s

79. k(m)
80. g(m)
81. f(m)
82. s(m)
83. z(m)

86. -pɚ

90. -kɚ
91. -gɚ

93. -ʃɚ

103. bl-

99. -ɚk

125. -pt

113. -lf

115. -sm

118. -ks
119. -mps

APPENDIX D

Program Output

The following pages illustrate the system with two sample cases; the first demonstrates the abbreviated input option, the second the full input option.

```
PATIENT ID ------------- 123456
NAME-------------------- J Smith
AGE--------------------- 6
SEX(IF BOY ENTER 1;IF GIRL ENTER 2)--- 1
EXAMINER---------------- T Harris
DATE-------------------- 9/2/73



SCREENING TEST
DO YOU WISH TO HAVE ABBREVIATED INPUT?(YES OR NO) yes
  1  er      3
  3  r(I)    w
  4  r(m)    w
  5  l(I)    7
  7  th(I)   f
  8  th(m)   f
  9  th(f)   f
 10  th-(I)  d
 11  th-(m)  d
 12  th-(f)  v
 13  z(I)    ok
 14  sh(I)   ds
 15  sh(m)   ok
 16  sh(f)   ds
 17  z-(m)   ok
 18  j(I)    h
 19  j(m)    21
 21  ch(m)   ds
 22  ch(f)   ts
 23  dz-(I)  ds
 24  dz-(m)  dz
 25  pr-     pE
 26  br-     bw
 27  tr-     tw
 28  dr-     d-
 29  kr-     tr
 30  gr-     dw
 31  fr-     f
 32  thr-    tw
 33  shr-    sl
 34  pl-     p-
 35  kl-     k-
 36  gl-     d-
 37  fl-     fw
 38  sm-     ok
 39  sn-     xn
 40  sp-     -p
 41  st-     -t
 42  sk-     xk
 43  sl-     thl
 44  sw-     46
 46  kw-     tw
 47  spl-    wae
 48  spr-    -p-
 49  str-    sw
 50  skr-    sw
ANY CHANGES IN DATA(YES OR NO) no

SCREENING TEST      12
CUT-OFF SCORE       34
DO YOU WISH TO CARRY ON THE TEST---    yes
 51  m       55
 55  ng      n
 56  p       72
 72  s       ds
 73  s       ds
 74  z       ds
 75  z-      dz
 76  h       78
 78  dz-     dz
 79  k(m)    82
 82  s(m)    th
 83  z(m)    ds
 84  -mr     92
 92  -th-r   dr
 93  -shr    xr
 94  -rm     101
101  -rch    rx
102  -rdz-   rx
103  bl-     bw
104  -pl     pl
105  -bl     ok
106  -tl     to
107  -kl     109
109  -sl     thl
110  -lp     114
114  -lz     lth-
115  -sm     thm
116  -st     tht
117  -sk     th-
118  -ks     kth
119  -mps    mpth
120  -ngk    125
125  -pt     p-
126  -ft     f-
127  l       142
ANY CHANGES IN DATA(YES OR NO) no
```

PATIENT ID	123456
NAME	J Smith
AGE	6YRS
SEX	BOY
EXAMINER	T Harris
OATE	9/2/73

COMPARISON WITH NORMS

	SCORE	NORM	SD
OIAGNOSTIC TEST (TABLE 1)	79	116.8	28.1
SCREENING TEST (TABLE 2)	12	38.5	13.8
CUT-OFF SCORE(TABLE 3)	--	34	
INITIAL AND FINAL CONSONANT SINGLES(TABLE 4)	26	35.6	7.1
INITIAL CONSONANTS(TABLE 5)	15	19.6	2.9
FINAL CONSONANTS(TABLE 6)	11	16.0	4.5
CONSONANTS OEFECTIVE AT ONE POSITION	11	--	
IOWA PRESSURE ARTICULATION TEST(TABLE 8)	17	35.5	10.3
/R/ ANO /R/ CLUSTERS(TABLE 9)	15	24.9	8.9
/L/ AND /L/ CLUSTERS(TABLE 10)	7	14.0	5.1
/S/ CLUSTERS(TABLE 11)	2	11.2	6.7
MISCELLANEOUS CLUSTERS(TABLE 12)	6	7.3	2.0
VOWELS(TABLE 13)	11	10.8	0.6
OIPHTHONGS(TABLE 14)	6	6.0	0.0

ANALYSIS OF MISARTICULATIONS

```
2-A. LIST ALL ERROR SOUNOS,INOICATING POSITION OF ERROR(I OR F)
     OMISSIONS:(AT INITIAL POS)  NONE
     OMISSIONS:(AT FINAL POS)  NONE
     SUBSTITUTIONS:(AT INITIAL POS) w  /r  ; f  /th ; d  /th-; h  /j  ;
     SUBSTITUTIONS:(AT FINAL POS) f  /th ; v  /th-; ts /ch ; n  /ng ; dz /z- ; dz /dz-;
     DISTORTIONS:(AT INITIAL POS) sh ; dz-; s  ;
     DISTORTIONS:(AT FINAL POS) sh ; s  ; z  ;

     2-B. PHONEMES CORRECT AT ONE POSITION
     AT INITIAL POSITION:  z  ;ch ;
     AT FINAL POSITION   NONE
     2-C. PHONEMES INCORRECTLY PRODUCED AS SINGLES,WERE CORRECTLY PRODUCED IN CLUSTERS
     ng :s  :
     DO YOU WANT STIMULATION TEST? yes
     2-D. PHONEMES CORRECTLY PRODUCED AFTER STIMULATION
     IN ISOLATION
      1  r    no
      2  th   no
      3  th-  no
      4  j    ok
      5  z-   ok
      6  dz-  no
      7  sh   ok
     OO YOU WANT TO CONTINUE?(YES OR NO) yes
     IN A SYLLABLE
      1  r    ok
      2  th   ok
      3  th-  no
      4  j    ok
      5  z-   ok
      6  dz-  no
      7  sh   no
     OO YOU WANT TO CONTINUE?(YES OR NO) no
     2-E. THE FOLLOWING PHONEMES WERE NEVER ARTICULATED CORRECTLY:
     th-;dz-;
  STOP     0
#23:05.26 4.345 RC=0
#
```

```
PATIENT ID ------------- 123456
NAME-------------------- J Smith
AGE--------------------- 6
SEX(IF BOY ENTER 1;IF GIRL ENTER 2)--- 1
EXAMINER---------------- T Harris
DATE-------------------- 9/2/73



SCREENING TEST
DO YOU WISH TO HAVE ABBREVIATED INPUT?(YES OR NO) no
 1  er      ok
 2  ju      ok
 3  r(I)    w
 4  r(m)    w
 5  l(I)    ok
 6  v(I)    ok
 7  th(I)   f
 8  th(m)   f
 9  th(f)   f
10  th-(I)  d
11  th-(m)  d
12  th-(f)  v
13  z(I)    ok
14  sh(I)   ds
15  sh(m)   ok
16  sh(f)   ds
17  z-(m)   ok
18  j(I)    h
19  j(m)    ok
20  ch(I)   ok
21  ch(m)   ds
22  ch(f)   ts
23  dz-(I)  ds
24  dz-(m)  dz
25  pr-     pE
26  br-     bw
27  tr-     tw
28  dr-     d-
29  kr-     tr
30  gr-     dw
31  fr-     f
32  thr-    tw
33  shr-    sl
34  pl-     p-
35  kl-     k-
36  gl-     d-
37  fl-     fw
38  sm-     ok
39  sn-     xn
40  sp-     -p
41  st-     -t
42  sk-     xk
43  sl-     thl
44  sw-     ok
45  tw-     ok
46  kw-     tw
47  spl-    wae
48  spr-    -p-
49  str-    sw
50  skr-    sw
    ANY CHANGES IN DATA(YES OR NO) no


    SCREENING TEST      12
    CUT-OFF SCORE       34
    DO YOU WISH TO CARRY ON THE TEST---    yes

         CONSONANTS SINGLES

 INITIAL      FINAL
51  m        52  m    ok    ok
53  n        54  n    ok    ok
             55  ng   --    n
56  p        57  p    ok    ok
58  b        59  b    ok    ok
60  t        61  t    ok    ok
62  d        63  d    ok    ok
64  k        65  k    ok    ok
66  g        67  g    ok    ok
             68  l    --    ok
69  f        70  f    ok    ok
             71  v    --    ok
72  s        73  s    ds    ds
             74  z    --    ds
             75  z-   --    dz
76  h                 ok
77  w                 ok
             78  dz-  --    dz

    OTHER PRESSURE CONSONANTS
79  k(m)    ok
80  g(m)    ok
81  f(m)    ok
82  s(m)    th
83  z(m)    ds
```

```
    R SYLLABIC
 84 -mr    ok
 85 -nr    ok
 86 -pr    ok
 87 -br    ok
 88 -tr    ok
 89 -dr    ok
 90 -kr    ok
 91 -gr    ok
 92 -th-r  dr
 93 -shr   xr

    R NON- SYLLABIC
 94 -rm    ok
 95 -rn    ok
 96 -rp    ok
 97 -rt    ok
 98 -rd    ok
 99 -rk    ok
100 -rf    ok
101 -rch   rx
102 -rdz-  rx

    ADDITIONAL L CLUSTERS
103 bl-    bw
104 -pl    pl
105 -hl    ok
106 -tl    to
107 -kl    ok
108 -gl    ok
109 -sl    thl
110 -lp    ok
111 -lt    ok
112 -lk    ok
113 -lf    ok
114 -lz    lth-

    ADDITIONAL S CLUSTERS
115 -sm    thm
116 -st    tht
117 -sk    th-
118 -ks    kth
119 -mps   pmth

    OTHER CLUSTERS
120 -ngk   ok
121 -mp    ok
122 -nt    ok
123 -nd    ok
124 -kt    ok
125 -pt    p-
126 -ft    t-

    ADDITIONAL VOWELS
127 I      ok
128 I :    ok
129 E      ok
130 ae     ok
131 A      ok
132 r      ok
133 a      ok
134 D      ok
135 U      ok
136 u      ok

    DIPHTHONGS
137 oU     ok
138 aU     ok
139 eI     ok
140 aI     ok
141 OI     ok
    ANY CHANGES IN DATA(YES OR NO) no




    PATIENT ID             123456
    NAME                   J Smith
    AGE                    6YRS
    SEX                    BOY
    EXAMINER               T Harris
    DATE                   9/2/73
```

COMPARISON WITH NORMS

	SCORE	NORM	SD
DIAGNOSTIC TEST (TABLE 1)	79	116.8	28.1
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CONSONANTS DEFECTIVE AT ONE POSITION	11	--	
IOWA PRESSURE ARTICULATION TEST(TABLE 8)	17	35.5	10.3
/R/ AND /R/ CLUSTERS(TABLE 9)	15	24.9	8.9
/L/ AND /L/ CLUSTERS(TABLE 10)	7	14.0	5.1
/S/ CLUSTERS(TABLE 11)	2	11.2	6.7
MISCELLANEOUS CLUSTERS(TABLE 12)	6	7.3	2.0
VOWELS(TABLE 13)	11	10.8	0.6
DIPHTHONGS(TABLE 14)	6	6.0	0.0

ANALYSIS OF MISARTICULATIONS

2-A. LIST ALL ERROR SOUNDS, INDICATING POSITION OF ERROR(I OR F)

OMISSIONS:(AT INITIAL POS) NONE

OMISSIONS:(AT FINAL POS) NONE

SUBSTITUTIONS:(AT INITIAL POS) w /r ; f /th ; d /th-; h /j ;

SUBSTITUTIONS:(AT FINAL POS) f /th ; v /th-; ts /ch ; n /ng ; dz /z- ; dz /dz-;

DISTORTIONS:(AT INITIAL POS) sh ; dz-; s ;

DISTORTIONS:(AT FINAL POS) sh ; s ; z ;

2-B. PHONEMES CORRECT AT ONE POSITION

AT INITIAL POSITION: z ;ch ;

AT FINAL POSITION NONE

2-C. PHONEMES INCORRECTLY PRODUCED AS SINGLES, WERE CORRECTLY PRODUCED IN CLUSTERS

ng :s :
DO YOU WANT STIMULATION TEST? yes

2-D. PHONEMES CORRECTLY PRODUCED AFTER STIMULATION

```
IN ISOLATION
 1  r     no
 2  th    no
 3  th-   no
 4  j     ok
 5  z-    ok
 6  dz-   no
 7  sh    ok
DO YOU WANT TO CONTINUE?(YES OR NO) yes

IN A SYLLABLE
 1  r     ok
 2  th    ok
 3  th-   no
 4  j     ok
 5  z-    no
 6  dz-   no
 7  sh    ok
DO YOU WANT TO CONTINUE?(YES OR NO) yes

IN A WORD
 1  r     ok
 2  th    ok
 3  th-   no
 4  j     ok
 5  z-    no
 6  dz-   no
 7  sh    ok
```

2-E. THE FOLLOWING PHONEMES WERE NEVER ARTICULATED CORRECTLY:

th-;dz-;

```
  STOP      0
#22:51.13 6.022 RC=0
#
```